Calibration of the XENON10 Detector

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for the XENON Collaboration

Prepared with \LaTeX
Outline

- Data Processing
  - Raw Data
  - Parameter Extraction
  - Position Reconstruction
  - Cuts

- Calibration
  - Purity and Light Yield Stability
  - Gamma Calibration
  - Neutron Calibration
  - ER Rejection Power
Data Processing
Raw Data

- The raw data for an event is composed of 89 signal traces of 16350 14 bits samples.
- Here is an example of a signal trace:

Sum up all 89 signal traces to make finding signal regions easier.

Which parameters do we need to extract?
Parameters Extracted
Parameters Extracted

- Pulse positions

![Graph showing time samples and pulse positions](image.png)

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Parameters Extracted

- Pulse positions
- Pulse extents
Parameters Extracted

- Pulse positions
- Pulse extents
- S1 pulse area
Parameters Extracted

- Pulse positions
- Pulse extents
- S1 pulse area
- S2 pulse area
Parameters Extracted

- Pulse positions
- Pulse extents
- S1 pulse area
- S2 pulse area

S1 pulse width
Parameters Extracted

- Pulse positions
- Pulse extents
- S1 pulse area
- S2 pulse area
- S1 pulse width
- S2 pulse width

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Parameters Extracted

- Pulse positions
- Pulse extents
- S1 pulse area
- S2 pulse area
- S1 pulse width
- S2 pulse width
- S1 pulse height
Parameters Extracted

- Pulse positions
- Pulse extents
- S1 pulse area
- S2 pulse area
- S1 pulse width
- S2 pulse width
- S1 pulse height
- S2 pulse height

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Parameters Extracted

- Pulse positions
- Pulse extents
- S1 pulse area
- S2 pulse area
- S1 pulse width
- S2 pulse width
- S1 pulse height
- S2 pulse height
- Drift time
Position Reconstruction

- Localization of events in three dimensions
  - The $z$ coordinate is determined by the drift time, the time between the S1 and S2 signals
  - The $x$ and $y$ positions are reconstructed from the distribution of the S2 signal on the top 48 PMTs
  - The position is obtained by using a multilayer perceptron neural network trained with Monte Carlo simulated distributions
  - Much more about position reconstruction in R. Santorelli’s talk
## Cuts

Three levels of cuts are applied to the WIMP search data:

<table>
<thead>
<tr>
<th>QC0: Basic quality cuts</th>
<th>QC1: Fiducial volume cuts</th>
<th>QC2: High level cuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed to remove noisy events, events with unphysical parameters or events which are not interesting for a WIMP search</td>
<td>Because of the high stopping power of LXe, fiducialization is a very effective way of reducing background.</td>
<td></td>
</tr>
<tr>
<td>■ S1 coincidence cut</td>
<td>■ $r &lt; 80\text{ mm}$</td>
<td>Cuts based on the distribution of the S1 signal on the top and bottom PMTs. They are designed to remove events with anomalous or unusual S1 patterns</td>
</tr>
<tr>
<td>■ S1 single peak cut</td>
<td>■ $15\mu s &lt; dt &lt; 65\mu s$</td>
<td>■ S1 top-bottom asymmetry cut</td>
</tr>
<tr>
<td>■ S2 saturation cut</td>
<td></td>
<td>■ S1 top RMS cut</td>
</tr>
<tr>
<td>■ S2 single peak cut</td>
<td></td>
<td>■ S1 bottom RMS cut</td>
</tr>
<tr>
<td>■ S2 width cut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>■ S2 $\chi^2$ cut</td>
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</tr>
</tbody>
</table>
Calibration
Purity and Light Yield Stability

- $^{137}\text{Cs}$ and $^{57}\text{Co}$ calibrations are performed at regular intervals to monitor stability.
- Infer $e^-$ lifetime by looking at the drift time dependence of the light yield of the $^{137}\text{Cs}$ 662 keV photo-absorption peak.
- Monitor light yield stability with $^{137}\text{Cs}$ photo-absorption peak and at low energy with characteristic x-ray peak ~30 keV.
Gamma Calibration

- Gamma calibration performed with a $^{137}\text{Cs}$ source
- 2400 events (78 live days equivalent) between 2 to 12 keVee in FV
- Procedure to define the ER band:

![Graph showing log$_{10}(S2/S1)$ vs. energy (E [keVee, 2.2 pe/keVee]) with data points scattered across the graph.]
Gamma Calibration

- Gamma calibration performed with a $^{137}\text{Cs}$ source
- 2400 events (78 live days equivalent) between 2 to 12 keVee in FV
- Procedure to define the ER band:
  - Fit ER band centroid

![Graph showing log10(S2/S1) vs E [keVee, 2.2 pe/keVee] with a fitted line]
Gamma Calibration

- Gamma calibration performed with a $^{137}\text{Cs}$ source
- 2400 events (78 live days equivalent) between 2 to 12 keVee in FV
- Procedure to define the ER band:
  - Fit ER band centroid
  - Straighten the band

![Graph showing ER vs E with data points and a fitted line]
Gamma Calibration

- Gamma calibration performed with a $^{137}$Cs source
- 2400 events (78 live days equivalent) between 2 to 12 keVee in FV
- Procedure to define the ER band:
  - Fit ER band centroid
  - Straighten the band
  - Fit energy slices

![Gamma Calibration Graph](image)
Neutron Calibration

- Neutron calibration performed with an AmBe source
- 8400 events (273 live days equivalent) between 2 to 12 keVee in FV
- Procedure to define the NR band:
Neutron Calibration

- Neutron calibration performed with an AmBe source
- 8400 events (273 live days equivalent) between 2 to 12 keVee in FV
- Procedure to define the NR band:
  - Plot the NR band relative to the ER band

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Neutron Calibration

- Neutron calibration performed with an AmBe source
- 8400 events (273 live days equivalent) between 2 to 12 keVee in FV
- Procedure to define the NR band:
  - Plot the NR band relative to the ER band
  - Fit energy slices

![Graph showing the relationship between ER and log \( \frac{S_2}{S_1} \) vs energy.]

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Rejection Power

- Region of interest defined as 2 to 12 keVee in energy with 50% nuclear recoil acceptance
- Compute the ER rejection from the gamma and neutron calibration results
- ~99.5% ER rejection at 50% NR acceptance
- More about nuclear recoil discrimination in A. Manalaysay’s and E. Dahl’s talks.